UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Electrification Administration

**BULLETIN 1753F-601(PE-90)**

**SUBJECT:** **Minimum Performance Specification for Fiber Optic Cables**

**TO:** All RDUP Telecommunication Borrowers
RDUP Telecommunication Staff

**EFFECTIVE DATE:**

**EXPIRATION DATE:** Date of change in 7 CFR 1755.900 by rulemaking.

**OFFICE OF PRIMARY INTEREST:** Technical support Branch, Advanced Services Division.

**PREVIOUS INSTRUCTIONS:** This bulletin replaces REA Specification for Filled Fiber Optic Cables dated August 4, 1994.

**FILING INSTRUCTIONS:** Discard **BULLETIN 1753F-601**, REA Specification for Filled Fiber Optic Cable, PE-90, dated August 4, 1994, and replace with this bulletin. This bulletin is a user friendly guide and a reformat of the text codified in 7 CFR 1755.900 published at 59 FR 34353. File with 7 CFR 1755 and on REANET.

Every effort has been made to ensure the accuracy of this document. However, in case of discrepancies, the regulations at 7 CFR 1755.900 are the authorized sources.

**PURPOSE:** This specification covers RDUP minimum requirements for fiber optic cables intended for aerial installation either by attachment to a support strand or by an integrated self-supporting arrangement, for underground application by placement in a duct, or for buried installations either by trenching or direct plowing. It can be reasonably be expected that the average bi-directional loss of fusion splices be 0.1 dB when using a cable manufactured to this specification. The maximum PMD of 0.5 ps/•km allowed by this specification corresponds to a PMD limited transmission distance (1 dB penalty) of approximately 400 km for digital OC-192 (10 Gbps) systems. The minimum meet-span allowed is 20 feet.

Administrator Date

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## ABBREVIATIONS

| | |
|---|---|
| ASTM | American Society For Testing and Materials |
| °C | Centigrade temperature scale |
| dB | Decibel |
| dB/km | Decibels per 1 kilometer |
| ECCS | Electrolytic chrome coated steel |
| EIA | Electronic Industries Association |
| EIA/TIA | Electronic Industries Association/ Telecommunications Industry Association |
| GE | General Electric |
| HD | High density polyethylene |
| LDHMW | Low density, high molecular weight polyethylene |
| LLDHMW | Liner low density, high molecular weight polyethylene |
| Max. | Maximum |
| MD | Medium density polyethylene |
| MHz-km | Megahertz-kilometer |
| Min. | Minimum |
| nm | nanometer(s) |
| NA | Numerical aperture |
| NESC | National Electrical Safety Code |
| OC | Optical cable |
| OF | Optical fiber |
| OSHA | Occupational Safety and Health Administration |
| % | Percent |
| PMD | polarization mode dispersion |
| ps/(nm·km) | Picosecond per nanometer times kilometer |
| ps/($nm^2$·km) | Picosecond per nanometer squared times kilometer |
| RDUP | Rural Development Utilities Programs |
| RUS | Rural Utilities Service |

## DEFINITIONS

**Armor**: A metal tape intended to provide protection against rodent and termites and provide environmental and general mechanical protection.

**Bandwidth:** The range of signal frequencies that can be transmitted by a communications channel with defined maximum loss or distortion. Bandwidth indicates the information-carrying capacity of a channel. For an optic fiber system bandwidth is usually given as its capacity to

transmit information in a specific time period for a specific length, e.g., 10 Mbit/sec/km.

**Chromatic Dispersion:** The spreading out of light pulses as they travel in an optical fiber, proportional to length.

**Cladding:** A layer of glass or other transparent material fused to and concentrically surrounding the core. The cladding has a lower refractive index than the core, so light is internally reflected along the core.

**Core:** The central region of an optical waveguide or fiber through which light is transmitted.

**Cutoff Wavelength:** The shortest wavelength at which only the fundamental mode of an optical wavelength is capable of propagation.

**Dielectric Cables:** Cable with no metallic members or other electrically conductive materials.

**Graded Refractive Index Profile:** Any index profile that varies smoothly with radius.

**Loose Tube Buffer:** A protective tube loosely surrounding a cabled fiber, often filled with suitable water blocking material.

**Mode-Field Diameter:** The diameter of the one mode of light propagating in a single mode fiber.

**Multimode Fiber:** An optical fiber which will allow more than one bound to propagate. It may be either a graded index or step index optical fiber.

**Numerical Aperture (NA):** An optical fiber parameter that indicates the angle of acceptance of light into a fiber.

**Optical Fiber:** Any fiber made of dielectric material that guides light.

**Optical Waveguide:** Any structure capable of guiding optical power. In optical communications, the term generally refers to a fiber designed to transmit optical signals.

**Optical Point Discontinuities**: localized deviation of the optical fiber loss characteristic which location and magnitude may be determined by OTDR by appropriate OTDR measurements

**Polarization Mode Dispersion**: A form of modal dispersion where different polarizations of the light caused by asymmetric distortions of the fiber from the ideal perfect shape of a cylinder travel at different speeds causing random spreading of optical pulses travel due to random imperfections in the fiber waveguide.

**Ribbon**: A planar array of parallel optical fibers.

**Shield**: Conductive metal tape to provide protection against lightning and electrical shielding.

**Single Mode Fiber:** An optical fiber in which only one bound mode can propagate at the wavelength of interest.

**Step Refractive Index Profile:** An index profile characterized by a uniform refractive index within the core and a sharp decrease in refractive index at the core-cladding interface. It corresponds to a power-law profile with profile parameter, g, approaching infinity.

**Tight Tube Buffer:** One or more layers of buffer material tightly surrounding a fiber in contact with the coating of the fiber.

## 1 SCOPE

**a** This specification covers the requirement for fiber optic cables intended for aerial installation either by attachment to a support strand or by an integrated self-supporting arrangement, for underground application by placement in a duct, or for buried installations either by trenching or by direct plowing.

**(1)** The optical waveguides are glass fibers having directly-applied protective coatings, and are called "fibers", herein. These fibers may be assembled in either loose fiber bundles with a protective core tube, encased in several protective buffer tubes, in tight buffer tubes, or ribbon bundles with a protective core tube.

**(2)** Fillers, strength members, core wraps, and bedding tapes may complete the cable core.

**(3)** The core or buffer tubes containing the fibers and the interstices between the buffer tubes, fillers, and strength members in the core structure are filled with a suitable material to exclude water.

**(4)** The cable structure is completed by an extruded overall plastic jacket. This jacket may have strength members embedded in it, in some designs.

**(5)** Buried installation requires armor under the outer jacket.

**(6)** For self-supporting cable the outer jacket may be extruded over the support messenger and cable core.

**b** The normal temperature ranges for cable under this specifications must meet paragraph 1.1.3 of ICEA S-87-640-2005. Table 1.1 – "Cable normal temperature ranges," is reproduced for information purposes only:

| | °C | (°F) |
|---|---|---|
| **Operation** | **-40 to +70** | **(-40 to +158)** |
| **Storage and Shipping** | **-40 to +70** | **(-40 to +158)** |
| **Installation** | **-30 to +60** | **(-22 to +140)** |

**c** **Tensile Rating:** The standard installation tensile rating for cable under this specification is 2670 N (600 lbf.)

**d** For self-supporting fiber optic service entrance cables, manufacturers must specify the maximum span length for all three storm loading districts referenced in Section 25, Loading of Grades B and C, of the latest edition of NESC. Additionally, to ensure the proper ground clearance (typically 4.3 m or 14 feet) is maintained the end user should factor in the maximum sag under loaded conditions as well as height of attachment for each application.

e **Minimum Bend Diameter**: For cable under loaded and unloaded conditions, the cable shall have the minimum bend diameters indicated in paragraph 1.1.5, Minimum Bend Diameter of the ICEA S-87-640 shown below for information purposes. For very small cables, manufacturers may specify fixed cable minimum bend diameters that are independent of the outside diameter.

(1) Residual (Installed): 20 times Cable O.D

(2) Loaded Condition during installation: 40 times Cable O.D.

**f** The cable is fully color coded so that each fiber is distinguishable from every other fiber. A basic color scheme of twenty-four colors allows individual fiber identification. Colored tubes, binders, threads, stripings, or markings provide fiber group identification.

**g** Cable manufactured to this specification must demonstrate compliance with the qualification testing requirements to ensure satisfactory end-use performance characteristics for the intended applications.

**h** Optical cable designs not specifically addressed by this specification may be allowed if accepted by RDUP. Justification for acceptance of a modified design must be provided to substantiate product utility and long term stability and endurance.

**i** All cables sold to RDUP borrowers for projects involving RDUP loan funds under this specification must be accepted by RDUP Technical Standards Committee "A" (Telecommunications). For cables manufactured to this specification, all design changes to an accepted design must be submitted for acceptance. RDUP will be the sole authority on what constitutes a design change.

**j** RDUP intends that the optical fibers contained in the cables manufactured in accordance with this specification have characteristics that will allow signals, having a range of wavelengths, to be carried simultaneously.

**2** OPTICAL FIBERS

**a** The solid glass optical fibers must consist of a cylindrical core and cladding covered by either an ultraviolet-cured acrylate or

other suitable coating. Each fiber shall be continuous throughout its length.

**b** Unless otherwise indicated by the purchaser, the dispersion-unshifted single mode fiber core must have either a matched or depressed clad step refractive index profile with a mode-field diameter of 9.2 ± 0.4 micrometers when measured at 1300 nm. The Non-zero Dispersion fiber must have a mode-field diameter of 10.5 ± 0.5 micrometers when measured at 1550 nm.

**c** All fibers delivered for an RUS financed project shall be manufactured to the same Mode Field Diameter (MFD), unless specific MFDs are required by the purchaser.

**d** Optical fibers shall meet the requirements of paragraphs 2.1 and 2.3.1 of ICEA S-87-640. From the ICEA S-87-640 Table 2.1 for single multimode and Table 2.2 of for single-mode fibers are reproduced here for information purposes only:

Table 2.1 - Multimode optical fiber specification requirements (1)

| Fiber Type | TIA/EIA Specification Reference | | |
|---|---|---|---|
| | Sectional | Blank Detail | Detail |
| 50 µm | 492A000 | 492AA00 | 492AAAB |
| 50µm (2) | 492A000 | 492AA00 | 492AAAC |
| 62.5 µm | 492A000 | 492AA00 | 492AAAA |
| Fiber Attributes (Informative)(3) | | | |
| Fiber Class and Subclass | Diameters (µm) | | Numerical Aperture |
| | Core | Cladding | |
| Ia | 50 +/- 3.0 | 125.0 ± 2.0 | 0.200 +/- 0.015 |
| | 62.5 +/- 3.0 | 125.0 ± 2.0 | 0.275 +/- 0.015 |

Notes

1) Fiber specifications listed herein are provided for convenience, but are dynamic and subject to change. Users should refer to the relevant TIA-492 detailed fiber specification for current requirements.

2) 850 nm laser-optimized 50 µm fiber

3) These attributes are defined by the Detailed Fiber Specifications called out above. The values are subject to change, and are included here for information, only. Refer to the latest fiber Specifications for current normative values.

Table 2.2 – Single-mode optical fiber specification requirements (1, 2)

| Fiber Class | Fiber Type | TIA/EIA Specification Reference(3) Sectional | Blank Detail | Detail |
|---|---|---|---|---|
| IVa | Dispersion Unshifted | 492C000 | 492CA00 | 492CAAA |

| | | | | |
|---|---|---|---|---|
| IVa | Dispersion Unshifted Low Water Peak | 492C000 | 492CA00 | 92CAAB |
| IVb | Dispersion Shifted | --- | 492BB00 | --- |
| IVd | Non-zero Dispersion | 492E000 | 492EA00 | --- |

Fiber Attributes (Informative) (4)

| | Diameter (µm) | | | Chromatic Dispersion | | |
|---|---|---|---|---|---|---|
| | Mode Field Diameter (Nominal) | Mode Field Diameter Tolerance | Cladding | Zero Dispersion Wavelength (nm) | Zero Dispersion Wavelength Slope Maximum ps/(nm2-km) | Dispersion Coefficient (ps/nm-km) |
| IVa | 8.8-9.3 @ 1310 nm | ± 0.5 | 125.0 ± 1.0 | 1300 – 1324 | 0.093 | Not Applicable |
| IVb(5) | 7.8-8.5 @ 1550 nm | ± 0.7 | 125.0 ± 1.0 | 1535 – 1565 | 0.085 | ≤ 2.7 |
| IVd | 7.2-11.0 @ 1550 nm | ± 0.7 | 125.0 ± 1.0 | Not Applicable | Not Applicable | (6) |

Notes:
1) Fiber specifications listed herein are provided for convenience, but are dynamic and subject to change.
Users should refer to the relevant TIA-492 detailed fiber specification for current requirements.

2) Missing references, including blank spaces in Table 2-2, indicate that no fiber Specification is available.

3) When no Detail Specification is available, fiber requirements shall be at the discretion of the cable manufacturer, unless otherwise agreed upon between manufacturer and user.

4) These attributes are defined by the Specifications called out above. The values are subject to change, and are included here for information only. Refer to the latest fiber Specifications for current normative values.

5) Fiber class IVb is provided for historical reference.

6) For class IVd dispersion coefficient: The manufacturer's declared wavelength range, λmin to λmax, shall satisfy 1530 nm < λmin < λ < λmax < 1565 nm. The absolute value of the dispersion coefficient D(λ) shall satisfy 1.0 = Dmin < |D| < Dmax = 10.0 ps/nm-km in the wavelength range of λmin and λmax. The absolute value of the difference between Dmin and Dmax shall be < 5.0 ps/nm-km.

**d** The individual fibers must be proof tested at a minimum tensile stress of 0.35 gigapascal for approximately one second when measured in accordance with EIA/TIA-455-31B.

**e** Factory splices of fibers are allowed provided, that all splices are documented and reported to the customer and that the spliced fiber meets all the requirements of this specification

**f** **Coating:** The optical fiber must be coated with a suitable material to preserve the intrinsic strength of the glass having an outside diameter of 250 ± 15 micrometers when measured in accordance with either EIA/TIA-455-55B or EIA/TIA-455-173. The protective coverings must be free from holes, splits, blisters, and other imperfections and must be as smooth and concentric as is consistent with the best commercial practice. The diameter of the fiber as the fiber is used in the cable includes any coloring thickness or the uncolored coating, as the case may be.

(1) The strip force required to remove 30 ± 3 millimeters of protective fiber coating shall be between 1.0 N and 9.0 N.

(2) Repairs to the fiber coatings are not allowed except at splice locations.

g All optical fibers in any single length of cable must of the same type.

**3 BUFFERS**

**a** The optical fibers contained in a tube buffer (loose tube), an inner jacket (unit core), a channel, or otherwise loosely packaged must have a clearance between the fibers and the inside of the container sufficient to allow for thermal expansions without constraining the fibers. The protective container must be manufactured from a material having a coefficient of friction sufficiently low to allow the fibers free movement. The lose tube shall contain a suitable water blocking material. Loose buffer tubes must be removable without damage to the fiber when following the manufacture's recommended procedures.

**b** The tube shall be designed to allow a minimum mid-span buffer tube exposure of 6 meters (20 ft)

**c** Optical fibers covered in near contact with an extrusion (tight tube) must have an intermediate soft buffer to allow for thermal expansions and minor pressures. The buffer tube dimension shall be established by the manufacturer to meet the requirement of this Specification. Tight buffer tubes must be removable without damage to the fiber when following the manufacture's recommended procedures. The tight buffered fiber shall be strippable in accordance with paragraph 7.20 of ICEA S-67-640-2005.

**d** All protective coverings in any single length of cable must be continuous and be of the same material except at splice locations.

**e** Both loose tube and tight tube coverings of each color and other fiber package types removed from the finished cable must meet the following shrinkback and cold bend performance requirements. The fibers may be left in the tube.

**(1)** **Shrinkback:** Testing must be conducted in accordance with ASTM D 4565-90a, Paragraph 14.1, using a talc bed at a temperature of 95°C. Shrinkback must not exceed 5 percent of the original 150 millimeter length of the specimen. The total shrinkage of the specimen must be measured.

**(2)** **Cold Bend:** Testing must be conducted on at least one tube from each color in the cable. Stabilize the specimen to -40 ± 1°C for a minimum of four hours. While holding the specimen and mandrel at the test temperature, wrap the tube in a tight helix ten times around a mandrel with a diameter not greater than five times the tube diameter. The tube must show no evidence of cracking when observed with normal or corrected-to-normal vision.

Note: Channel cores and similar slotted single component core designs need not be tested for cold bend.

## 4 FIBER AND BUFFER TUBE IDENTIFICATION

**a** Each tube in a multi-tube cable design shall be uniquely identifiable.

**b** The colors designated for identification of loose buffer tubes, tight tube buffer fibers, individual fibers in multi-fiber tubes, slots, bundles or units of fibers, and the units in cables with more than one unit shall be in accordance with TIA-598, *Optical Fiber Cable Color Coding,* shown on Table 4.1 reproduced from ICEA S-87-640-2005 for information purposes:

**Table 4.1 - Individual fiber, unit, and group identification**

| Position number | Base color and tracer | Abbreviation/print legend |
|---|---|---|
| 1 | Blue | 1 or BL or 1-BL |
| 2 | Orange | 2 or OR or 2-OR |
| 3 | Green | 3 or GR or 3-GR |
| 4 | Brown | 4 or BR or 4-BR |
| 5 | Slate | 5 or SL or 5-SL |
| 6 | White | 6 or WH or 6-WH |
| 7 | Red | 7 or RD or 7-RD |
| 8 | Black | 8 or BK or 8-BK |
| 9 | Yellow | 9 or YL or 9-YL |
| 10 | Violet | 10 or VI or 10-VI |
| 11 | Rose | 11 or RS or 11-RS |
| 12 | Aqua | 12 or AQ or 12-AQ |
| 13 | Blue with Black Tracer | 13 or D/BL or 13-D/BL(1) |
| 14 | Orange with Black Tracer | 14 or D/OR or 14-D/OR |
| 15 | Green with Black Tracer | 15 or D/GR or 15-D/GR |
| 16 | Brown with Black Tracer | 16 or D/BR or 16-D/BR |
| 17 | Slate with Black Tracer | 17 or D/SL or 17-D/SL |
| 18 | White with Black Tracer | 18 or D/WH or 18-D/WH |
| 19 | Red with Black Tracer | 19 or D/RD or 19-D/RD |
| 20 | Black with White Tracer | 20 or D/BK or 20-D/BK(2) |
| 21 | Yellow with Black Tracer | 21 or D/YL or 21-D/YL |

| | | |
|---|---|---|
| 22 | Violet with Black Tracer | 22 or D/VI or 22-D/VI |
| 23 | Rose with Black Tracer | 23 or D/RS or 23-D/RS |
| 24 | Aqua with Black Tracer | 24 or D/AQ or 24-D/AQ |
| 25 | Blue with Double Black Tracer | 25 or DD/BL or 25-DD/BL(3) |
| 26 | Orange with Double Black Tracer | 26 or DD/OR or 14-DD/OR |
| 27 | Green with Double Black Tracer | 27 or DD/GR or 15-DD/GR |
| 28 | Brown with Double Black Tracer | 28 or DD/BR or 16-DD/BR |
| 29 | Slate with Double Black Tracer | 29 or DD/SL or 17-DD/SL |
| 30 | White with Double Black Tracer | 30 or DD/WH or 18-DD/WH |
| 31 | Red with Double Black Tracer | 31 or DD/RD or 19-DD/RD |
| 32 | Black with Double White Tracer | 32 or DD/BK or 20-DD/BK(2) |
| 33 | Yellow with Double Black Tracer | 33 or DD/YL or 21-DD/YL |
| 34 | Violet with Double Black Tracer | 34 or DD/VI or 22-DD/VI |
| 35 | Rose with Double Black Tracer | 35 or DD/RS or 23-DD/RS |
| 36 | Aqua with Double Black Tracer | 36 or DD/AQ or 24-DD/AQ |

**Notes:**
1) "D/" denotes a dashed mark or tracer. That is, D/BL is Dash/Blue, meaning Blue with a tracer.
2) Pertaining to positions 20 and 32, yellow tracers are also allowed.
3) "DD/" denotes a double dashed mark or tracer. That is, DD/BL is Double Dash/Blue, meaning Blue with a double tracer.

**c** **Standards of Colors:** Except for the aqua color, the colors of fibers and tubes supplied in accordance with this specification are specified in terms of the Munsell Color System (ASTM D 1535-89) and must comply with the color limits as defined in EIA/TIA-598. (A visual color standard meeting these requirements and entitled "Munsell Color Charts for Color Coding," may be obtained from the Munsell Color Company, Inc., 2441 North Calvert Street, Baltimore, Maryland 21218. The latest edition of the color standard should be used.)

**(1)** The aqua color limits using the Munsell Color System must be as follows:

Munsell Notation

| Symbol | Aqua Color |
|---|---|
| Centriod | 10BG 7/6 |
| H++ | 5B 7/6 |
| H-- | 5BG 7/6 |
| V++ | 10BG 8/4 |
| V-- | 10BG 6/6 |
| C++ | None |
| C-- | 10BG 7/4 |

**(2)** Other coloring schemes used for providing identification of buffer tubes and optical fibers which deviate from the requirements of Paragraph 4.1 of this specification will not be accepted by RDUP.

**5 Optical Fiber Ribbon**

**a** Each ribbon shall be identified per Paragraphs 3.41 and 3.42 of ICEA S-87-640-2005.

**b** Ribbon fiber count shall be specified by the purchaser, i.e. 2,4,6,12, etc.

**c** Ribbon dimensions shall be as agreed by the purchaser and manufactures in accordance with Paragraphs 3.4.4.1 of ANSI/ICEA S-87-640-2005.

**d** Ribbons shall meet each of the following tests. These tests are included in the paragraphs of ICEA S-87-640-2005 indicated in parenthesis:

(1) Ribbon Twist Test (7.15) – evaluates the ability of the ribbon to resist splitting or other damage while undergoing dynamic cyclically twisting the ribbon under load

(2) Ribbon Residual Twist Test (7.16) – evaluate the degree of permanent twist in a cabled optical ribbon

(3) Ribbon Separability Test (7.17) – evaluate the ability to separate fibers

**e** Ribbons shall meet Paragraph 3.4.4.6 of ICEA S-87-640-2005, Ribbon Strippability.

**5 STRENGTH MEMBERS**

**a** Strength members must be an integral part of the cable construction, but are not considered part of the support messenger for self-supporting optical cable.

**b** The strength members may be metallic or nonmetallic.

**c** The combined strength of all the strength members must be sufficient to support the stress of installation and to protect the cable in service.

**d** Strength members may be incorporated into the core as a central support member or filler, as fillers between the fiber packages, as an annular serving over the core, as an annular serving over the intermediate jacket, embedded in the outer jacket or as a combination of any of these methods.

**e** The central support member or filler must contain no more than one splice per kilometer of cable. Individual fillers placed between the fiber packages and placed as annular servings over the core must contain no more than one splice per kilometer of cable.

Cable sections having central member or filler splices must meet the same physical requirements as un-spliced cable sections.

**f** In each length of completed cable having a metallic central member, the dielectric strength between the armor and the metallic center member must withstand at least 15 kilovolts direct current for 3 seconds.

## 6 FORMING THE CABLE CORE

**a** Protected fibers must be assembled with the optional central support member, fillers and strength members in such a way as to form a cylindrical group.

**b** The standard cylindrical group or core designs shall consist of 4, 6, 8, 10, 12, 16, 18, 20, or 24 fibers. Cylindrical groups or core designs larger than the sizes shown above must meet all the requirements of this specification.

**c** When treads or tapes are used as core binders, they must be colored either white or natural and must be a non-hygroscopic and non-wicking dielectric material.

**d** When treads or tapes are used as unit binders to define optical fiber units in loose tube, tight tube, slotted, or bundled cored designs, they must be colored in accordance with the table listed below and must be a non-hygroscopic and non-wicking dielectric material or be rendered such by the filling compound. The colors of the binders must be in accordance with Paragraphs 4.b and 4.c of this specification.

## 7 FILLING COMPOUND

**a** To prevent the ingress of water into the core and water migration, a suitable filling compound or water blocking elements must be applied into the interior of the loose fiber tubes and into the interstices of the core. When a core wrap is used, the filling compound water or blocking elements, as the case may be, must also be applied to the core wrap, over the core wrap and between the core wrap and inner jacket when required.

**b** The materials must be homogeneous and uniformly mixed; free from dirt, metallic particles and other foreign matter; easily removed; nontoxic and present no dermal hazards. The filling compound shall contain a suitable antioxidant to provide long term stability.

**c** The individual cable manufacturer must satisfy RDUP that the filling compound or water blocking elements selected for use is suitable for its intended application. The filling compound or water blocking elements must be compatible with the cable components when tested in accordance with ASTM D 4568-86 at a temperature of 80°C. The jacket strength shall retain a minimum of 85% of their un-aged tensile and elongation values.

## 8 FLOODING COMPOUND

**a** Sufficient flooding compound or water blocking elements must be applied between the inner jacket and armor and between the armor and outer jacket so that voids and air spaces in these areas are minimized. The use of floodant or water blocking elements between the armor and outer jacket is not required when uniform bonding, paragraph 11.f of this specification, is achieved between the plastic-clad armor and the outer jacket.

**b** The flooding compound or water blocking elements must be compatible with the jacket when tested in accordance with ASTM D 4568-86 at a temperature of 80°C (176°F ± 2°F). The aged Jacket shall retain a minimum of 85% of its unaged tensile strength and elongation values. The floodant must exhibit adhesive properties sufficient to prevent jacket slip when tested in accordance with the requirements of Appendix A, Paragraph 3.3, of this specification.

**c** The individual cable manufacturer must satisfy RDUP that the flooding compound selected for use is acceptable for the application.

## 9 CORE WRAP (OPTIONAL)

**a** At the option of the manufacturer, one or more layers of non-hygroscopic and non-wicking dielectric material may be applied over the core.

**b** The core wrap(s) can be used to provide a heat barrier to prevent deformation or adhesion between the fiber tubes or can be used to contain the core.

**c** When core wraps are used, sufficient filling compound must be applied to the core wraps so that voids or air spaces existing between the core wraps and between the core and the inner side of the core wrap are minimized.

## 10 INNER JACKET

**a** Inner jackets shall be applied directly over the core or over the strength members when required by the purchaser. The jacket must be free from holes, splits, blisters, or other imperfections and shall be as smooth and concentric as is consistent with the best commercial practice. The inner jacket shall not adhere to other cable components such as fibers, buffer tubes, etc.

**(1)** For armored cable an inner jacket is optional but recommended. The inner jacket may absorb stresses in the cable core that may be introduced by armor application or by armored cable installation.

**(2)** For unarmored cable an inner jacket is optional.

**b** The inner jacket material and test requirements must be as for the outer jacket material of this specification, except that either black or natural polyethylene may be used and the thickness requirements are included in paragraph 10c below. In the case of natural polyethylene, the requirements for absorption coefficient and the inclusion of furnace black are waived.

**c** Thickness: The inner jacket thickness shall meet the requirement of paragraph 7.1.2 of ICEA s-98-688-2005. The following table is reproduced from the ICEA standard for information purposes:

| Diameter (d) over Core Wrap mm (in) | Minimum Jacket Thickness | |
|---|---|---|
| | mm | (in) |
| Less than 25 (1.00) | 0.9 | (0.305) |
| 25 (1.00) to 45 (1.77) | 1.1 | (0.045) |
| Greater than 45 (1.77) | 1.4 | (0.055) |

**11 OUTER JACKET**

**a** The outer jacket must provide the cable with a tough, flexible, protective covering which can withstand exposure to sunlight, to atmosphere temperatures and to stresses reasonably expected in normal installation and service.

**b** The jacket must be free from holes, splits, blisters, or other imperfections and shall be as smooth and concentric as is consistent with the best commercial practice.

**c** The raw material used for the outer jacket must be one of the types listed in below. The raw material must contain an antioxidant to provide long term stabilization and the materials must contain a 2.60 ± 0.25 percent concentration of furnace black to provide ultraviolet shielding. Both the antioxidant and furnace black must be compounded into the material by the raw material supplier.

**(1)** Type L1. Low density, high molecular weight polyethylene (LDHMW) must conform to the requirements of ASTM D 1248, Type I, Class C, Category 4 or 5, Grade J3.

**(3)** Type L2. Linear low density, high molecular weight polyethylene (LLDHMW) must conform to the requirements of ASTM D 1248-84(1989), Type I, Class C, Category 4 or 5, Grade J3.

**(4)** Type M. Medium density polyethylene (MD) must conform to the requirements of ASTM D 1248-84(1989), Type II, Class C, Category 4 or 5, Grade J4.

**(5)** Type H. High density polyethylene (HD) must conform to the requirements of ASTM D 1248, Type III, Class C, Category 4 or 5, Grade J4.

**d** Particle size of the carbon selected for use must not average greater than 20 nm.

**e** Absorption coefficient must be a minimum of 400 in accordance with the procedures of ASTM D 3349.

**f** The outer jacketing material removed from or tested on the cable shall be capable of meeting the following performance requirements of Table 5.1 below. This table is reproduction of Table 5.1 found in ANSI ICEA S-87-640-2005, but some of the requirements shown in bold font have been changed. Cable manufactured to this specification shall meet the modified requirements as indicated in the table below. The tests methods are indicated by numbers referring to the appropriate paragraphs or sections of ANSI ICEA S-87-640-2005.

**Modified Table 5.1 – Jacket Requirements (1)**

| **Polyethylene Material** | | **PHYSICAL PERFORMANCE BY JACKET TYPE** | | | |
|---|---|---|---|---|---|
| **PROPERTY (2)** | **Test Method(7)** | **L1** | **L2** | **M** | **H** |
| Density(3) - g/cm$^3$<br>- Minimum<br>- Maximum | 7.7 | <br>0.920<br>0.940 | <br>0.925<br>0.945 | <br>0.940<br>0.955 | <br>0.952<br>0.973 |
| Ultimate Elongation<br>- Un-aged % Minimum | 7.8 | 400 | 400 | 400 | 300 |
| Yield Strength<br>- Mpa (psi) Minimum | 7.8 | **12**<br>() | **12**<br>(1200) | **16.5**<br>() | 19.3<br>() |
| Absorption Coefficient (4)<br>- ABS/mm Minimum | 7.9 | 400 | 400 | 400 | 400 |
| Environmental Stress Crack Resistance (5)<br>- Hours – Minimum<br>- Failures Allowed<br>- ASTM D 1693 Cond. | 7.10 | <br>48<br>2/10<br>A | <br>48<br>0/10<br>A | <br>48<br>2/10<br>B | <br>48<br>2/10<br>B |
| Environmental Stress Crack Resistance (6)<br>(small diameter cables)<br>- Failures Allowed | 7.10 | <br><br>0/1 | <br><br>0/1 | <br><br>0/1 | <br><br>0/1 |
| Jacket Shrinkback<br>- Oven Temp. - °C<br>- Test Time – hours<br>- Shrinkback % Maximum | 7.11 | <br>100 ± 1<br>4<br>5 | <br>100 ± 1<br>4<br>5 | <br>115 ± 1<br>4<br>5 | <br>115 ± 1<br>4<br>5 |
| **Notes:**<br>1) Jackets shall be removed from bonded sheath constructions in accordance with one of the two procedures provided under the "Jacket Notch Test" of | | | | | |

ASTM D 4565.

2) Test methods designating "clean sample" require that any residual flooding or bonding compounds be removed from the surface of the sample by other than chemical means. Those not so designated shall include these materials if they cling to the jacket.

   For jackets with embedded strength members, all tests except Environmental Stress Crack Resistance are for the material without the strength members.

3) The material densities are listed in terms of the as-received resin. The density of the natural resin is characteristically lower by some amount, due to the addition of carbon black and other additives. As a rule-of-thumb, the density of the natural resin is 0.012 g/cm3 lower when using the nominal concentration of carbon black (2.6% by weight.)

4) Requirements for Absorption Coefficient of the raw material may be substituted for tests on completed cable.

5) This Stress Crack Resistance requirement applies only to cables having an outside diameter of 30 mm (1.2 in) or greater.

6) For cables with outside diameters less than 30 mm (1.2 in), Stress Crack Resistance requirements shall be accomplished by testing the cable as a whole in accordance with ANSI ICEA SA-87-640-2005, paragraph10.2.

7) For test method see the **indicated** paragraph of ANSI ICEA SA-87-640-2005.

**e** **Testing Procedures:** The procedures for testing the jacket specimens for compliance with Paragraph 11f of this specification must be as follows:

(1) **Jacket Density:** Test per paragraph 7.7.1 of ICEA S-87-640-2005.

(2) **Tensile Strength and Ultimate Elongation**. Test per Section 7.8 of ICEA S-87-640-2005.

(3) **Absorption Coefficient Test:** Test per paragraph 7.9.1 of ICEA S-87-640-2005. The jacket shall meet the mechanical requirements on the Modified Table 5.1 above.

**(4)** **Environmental Stress Crack Resistance Test**: For large cables (outside diameter ≥ 30 mm (1.2 in)), test according with 7.10.1 and 7.10.1.1of ANSI/ICEA S-87-640-2005. For small cables (Diameter < 30 mm (1.2 in)), test per paragraphs 7.10.2 and 7.10.2.1 of ICEA S-87-640-2005. A cracked or split in the jacket constitutes failure.

**(5)** **Jacket Shrinkage Test**: Test per paragraphs 7.11.1 of ICEA S-640-2005. Samples removed from the completed cable shall meet the requirements of Modified Table 5.1 above.

**f** **Jacket Thickness:** The nominal outer jacket thickness must not be less than 1.3 millimeters. The test method used must be either the End Sample Method (Paragraph 11g(1) of this specification) or the Continuous Uniformity Thickness Gauge Method (Paragraph 11g(2)of this specification).

**g** **(1)** **End Sample Method:** The jacket must be capable of meeting the following requirements:

**(a)** Minimum Average Thickness shall be 90 % of nominal thickness

**(b)** Minimum Spot Thickness shall be 70 % of nominal thickness

**(2)** **Continuous Uniformity Gauge:** The jacket must be capable of meeting the following requirements:

**(a)** Minimum Average Thickness shall be 75 % of nominal thickness

**(b)** Minimum Thickness shall be 70 % of nominal thickness

**(c)** Maximum Eccentricity shall be 40 % of nominal thickness

$$\text{Eccentricity} = \frac{\text{Max. Thickness - Min. Thickness}}{\text{Average Thickness}} \times 100$$

**(d)** The maximum and minimum thickness values shall be based on the average of each axial section.

**g** For jackets having embedded strength members, the jacket thickness must meet the requirements of Paragraph 11f of this specification except that the jacket thickness over the strength members must not be less than 0.50 millimeters.

**h** The minimum jacket thickness at any point over the support messenger for self-supporting aerial cable utilizing such an element must be 1.1 millimeters.

**i** The web dimension for self-supporting aerial cable utilizing such a feature must be as follows:

(1) Height: 2.29 $\pm$ 0.750 millimeters

(2) Width: 1.52 + 0.51 millimeters

- 0.25 millimeters

**12 ARMOR**

**a** **11.1** A steel armor, plastic coated on both sides, is required for direct buried cable manufactured under this specification. Armor is optional for duct and aerial cable, as required by the purchaser. The plastic coated steel armor must be applied longitudinally directly over the core wrap or the intermediate jacket and have a minimum overlap of 3.0 millimeters. When a cable has a shield, the armor must be applied over the shielding tape.

**b** The uncoated steel tape must be electrolytic chrome coated steel (ECCS) per ASTM A 657 with a thickness of 0.155 ± 0.015 millimeters. The minimum thickness of the coating shall be 0.038 mm (0.0015 in.) and must be the following performance requirements prior to application to the wire when tested per ASTM A 370:

| Property | Requirement |
|---|---|
| Tensile Strength<br>Minimum, MPa (psi) | 414 (60,000) |
| Tensile Yield<br>Minimum, MPa (psi) | 241 (35,000) |
| Elongation<br>Minimum, percent in 50 mm (2 in) | 15 |

**c** The reduction in thickness of the armoring material due to the corrugating or application process must be kept to a minimum and must not exceed 10 percent at any spot.

**d** The armor of each length of cable must be electrically continuous with no more than one joint or splice allowed in any length of one kilometer of cable. This requirement does not apply to a joint or splice made in the raw material by the raw material manufacturer.

**e** The breaking strength of any section of an armor tape, containing a factory splice joint, must not be less than 80 percent of the breaking strength of an adjacent section of the armor of equal length without a joint.

**f** For cables containing no floodant over the armor, the overlap portions of the armor tape must be bonded in cables having a flat, noncorrugated armor to meet the mechanical requirements of Paragraph 18a through Paragraph 18m of this specification. If the tape is corrugated, the overlap portions of the armor must be sufficiently bonded and the corrugations must be sufficiently in

register to meet the requirements of Paragraphs 18a through Paragraph 17m of this specification.

**g** The armor tape must be so applied as to enable the cable to pass the bend test as specified in Paragraph 18.a of this specification.

**h** The protective coating on the steel armor must meet the Bonding-to-Metal, Heat Sealability, Lap-Shear and Moisture Resistance requirements of Type I, Class 2 coated metals in accordance with ASTM B 736-92a.

**i** The ability of the plastic-clad metal to resist the flooding compound must be determined as required by ASTM D4568 using a one meter length of coated steel which must be aged for 7 days at 68 ± 1°C. There must be no delamination of the coating from the steel at the conclusion of the test.

**j** When the jacket is bonded to the plastic coated armor, the bond between the plastic coated armor and the outer jacket must not be less than 525 Newtons per meter over at least 90 percent of the cable circumference when tested in accordance with ASTM D 4565-90a. For cables with strength members embedded in the jacket, and residing directly over the armor, the area of the armor directly under the strength member is excluded from the 90 percent calculation.

## 13 OPTIONAL SHIELD

**a** When required by the purchaser a corrugated shield must be applied longitudinally over the core wrap or over the inner jacket when one is used in the cable.

**b** When an dual shield of aluminum and steel is specified by the purchaser, the aluminum tape must be applied first over the core wrap or the inner jacket and the steel tape must be applied directly over the aluminum tape.

**c** Successive lengths of shielding tape may be joined during manufacturing by means of cold weld, electric weld, soldering with nonacid flux, or other acceptable means.

**d** General requirements for application of the shielding materials are as follows:

**(1)** Successive lengths of shielding tapes may be joined during the manufacturing process by means of cold weld, electric weld, soldering with a nonacid flux or other acceptable means.

**(2)** Where two ends of a metal shield are to be joined together, care shall be taken to clean the metal surfaces to provide for a good mechanical and electrical connection.

**(3)** The shields of each length of wire must be tested for continuity. A one meter (3 ft) section of shield containing a factory joint must exhibit not more than 110 percent of the resistance of a shield of equal length without a joint.

**(4)** The breaking strength of any section of a shield tape containing a factory joint must not be less than 80 percent of the breaking strength of an adjacent section of the shield of equal length without a joint.

**(5)** The reduction in thickness of the shielding material due to the corrugating or application process must be kept to a minimum and must not exceed 10 percent at any spot.

**(6)** The shield must be corrugated per the requirements of ANSI/ICEA S-99-689-2006 Paragraph 6.3.1.

**(7)** The shield edge overlap must comply with ANSI/ICEA S-99-689-2006 Paragraph 6.3.1.

**(6)** The corrugation extensibility of the coated aluminum shield must comply with the requirements specified in ANSI/ICEA S-689-608 Paragraph 6.4.

**(7)** The shielding material must be applied in such a manner as to enable the wire to pass the bend test as specified in Paragraph 17a of this specification.

**(8)** The minimum thickness of a coating applied to a shield tape shall be 0.038 mm (0.0015 in.)

**(9)** The plastic coated aluminum shield shall be tested for resistance to water migration by immersing a one meter (3 ft) length of tape under a one meter (3 ft) head of water containing a soluble dye plus 0.25 percent (%) wetting agent.

After a minimum of 5 minutes, no dye shall appear between the interface of the shield tape and the plastic coating.

**(10)** The bond between the plastic coated shield and the jacket shall conform to the following requirements:

**(a)** Prepare test strips approximately 200 mm (8 in.) in length. Slit the jacket and shield longitudinally to produce 4 strips evenly spaced and centered in 4 quadrants on the jacket circumference. One of the strips shall be centered over the overlapped edge of the shielding tape. The strips shall be 13 mm (0.5 in.) wide. For cable diameters less than 19 mm (0.75 in.) make two strips evenly spaced.

**(b)** Separate the shield and jacket for a sufficient distance to allow the shield and jacket to be fitted in the upper and lower jaws of a tensile machine. Record the maximum force required to separate the shield and jacket to the nearest newton (pound-force). Repeat this action for each test strip.

**(c)** The force required to separate the jacket from the shield shall not be less than 9 N (2 lbf) for any individual strip when tested in accordance with Paragraph 6.9.2 of this specification. The average force for all strips of any cable shall not be less than 18 N (4 lbf).

**e** The following materials are acceptable for use as shields:

| **Standard Wire** | **Gopher Resistant Wire** |
|---|---|
| 8 Mil Coated Aluminum[1] | 10 Mil Copper |
| 5 Mil Copper | 5 Mil Cooper-Clad Stainless Steel |
| 10 Mill Copper Alloy 220(Bronze) | 5 Mil Copper-Clad alloy Steel |
| | 6 Mil Copper Alloy 194 |
| | 7 Mill Copper Alloy |
| | 8 Mil Coated aluminum[1] & 6 mil coated Steel[1] |

**f** The required tape thickness for the shielding tapes listed in Paragraph 12e are indicated below:

| **Standard** | **Thickness in mm (in)** | |
|---|---|---|
| | **Nominal** | **Minimum** |
| 8 Mil Coated Aluminum[1] | 0.20 (0.008) | 0.18 (0.007) |
| 5 Mil Copper | 0.13 (0.005) | 0.12 (0.0046) |
| 10 Mill Copper Alloy 220(Bronze) | 0.10 (0.004) | 0.08(0.0032) |
| **Gopher Resistant** | | |
| 10 Mil Copper | (0.010) | (0.0096) |
| 5 Mil Cooper-Clad Stainless Steel | `0.13 (0.005) | 0.11 (0.0045) |
| 5 Mil Copper-Clad alloy Steel | `0.13 (0.005) | 0.11 (0.0045) |
| 6 Mil Copper Alloy 194 | 0.15 (0.006) | .014 (0.0055) |
| 7 Mill Copper Alloy | 0.18 (0.007) | 0.17 (0.0065) |
| 8 Mil Coated aluminum[1] & 6 mil | | 0 |

coated Steel[1]

[1]Dimension of the uncoated metal tape

**(1)** The coated aluminum tape must be plastic coated on both sides and shall comply with ANSI/ICEA S-98-688-2006 Paragraph B.1.2.

**(2)** The copper, copper alloy 220, and copper 194 alloy tapes must comply with ANSI/ICEA S-98-688-2006 Paragraph B.1.3.

The 6-mill 194 copper alloy tape shall be used for cables with an overall jacket diameter greater than 15mm (0.60 in) and the 7-mill tape for cables of 15 mm (0.60 in) diameter and smaller.

**(3)** The copper clad stainless steel must be in the fully annealed condition and must conform to the requirements of ASTM B 694, with a copper/steel/copper cladding ratio of 16/68/16.

The electrical conductivity of the clad tape must be a minimum of 28 percent of the International Annealed Copper Standard (IACS), when measure per ASTM 193.

**(4)** The copper clad alloy steel tapes must be in the fully annealed condition and the copper component must conform to the requirements of ASTM B 224 and the alloy steel component must conform to the requirements of ASTM 505, with a with a copper/steel/copper cladding ratio of 16/68/16.

The electrical conductivity of the clad tape must be a minimum of 28 percent of the IACS, when measure per ASTM 193.

**(5)** The 6-mill coated steel must be must be chrome coated steel (ECCS) per ASTM A 657 plastic coated on both sides capable of meeting the following performance requirements prior to application to the wire when tested per ASTM A 370:

| Property | Requirement |
|---|---|
| Tensile Strength<br>Minimum, MPa (psi) | 414 (60,000) |
| Tensile Yield<br>Minimum, MPa (psi) | 241 (35,000) |
| Elongation<br>Minimum, percent in 50 mm (2 in) | 15 |

**14 OPTIONAL SUPPORT MESSENGER (AERIAL CABLE)**

**a** When self-supporting aerial cable containing an integrated support messenger is supplied, the support messenger must comply with the requirements specified in Paragraphs 12.2 through 12.6 of this specification.

**b** The fully flooded, stranded support messenger must be 6.35 millimeters diameter, 7 wire, extra high strength grade, Class A galvanized steel strand conforming to ASTM A 640-91 with exceptions and additional provisions as follows:

**(1)** The maximum lay of the individual wires of the strand must be 140 millimeters.

**(2)** Any section of a completed strand containing a joint must have minimum tensile strength and elongation of 29,500 newtons and 3.5 percent, respectively, when tested in accordance with the procedures specified in ASTM A 640-91.

**(3)** The individual wires from a completed strand which contain joints must not fracture when tested according to the "Ductility of Steel" procedures specified in ASTM A 640-91 except that the mandrel diameter must be equal to 5 times the nominal diameter of the individual wires.

**c** The support strand must be completely covered with a corrosion protective floodant. The floodant must be homogeneous and uniformly mixed.

d The floodant must be nontoxic and present no dermal hazard.

**e** The floodant must be free from dirt, metallic particles, and other foreign matter that may interfere with the performance of the cable.

**f** The floodant must be compatible with the polyethylene outer jacket.

**g** Other methods of providing self-supporting cable specifically not addressed in this section may be allowed if accepted by RDUP. Justification for acceptance of a modified design must be provided to substantiate product utility and long term stability and endurance.

**15 SHEATH SLITTING CORD (OPTIONAL)**

**a** A sheath slitting cord is optional.

**b** When a sheath slitting cord is used it must be non-hygroscopic and non-wicking or be rendered such by the filling or flooding compound, continuous throughout a length of cable and of

sufficient strength to open the sheath over at least a one meter length without breaking the cord at a temperature of 23 ± 5°C.

**c** The sheath slitting cord must meet the sheath slitting cord test depicted in paragraph 18n of this specification.

**16 IDENTIFICATION MARKER AND LENGTH MARKER**

**a** Each length of cable shall be permanently identified. The method of marking must be by means of suitable surface markings producing a clear distinguishable contrasting marking meeting Paragraph 6.1.1 of ICEA S-87-640-2005 and shall meet the durability requirements of Paragraph 7.5.2 through 7.5.2.2 of ICEA S-87-640-2005.

**b** The color of the initial marking must be white or silver. If the initial marking fails to meet the requirements of the preceding paragraphs, it will be permissible to either remove the defective marking and re-mark with the white or silver color or leave the defective marking on the cable and re-mark with yellow. No further re-marking is permitted. Any re-marking must be on a different portion of the cables circumference than any existing marking when possible and have a numbering sequence differing from any other marking by at least 3,000. Any reel of cable that contains more than one set of sequential markings must be labeled to indicate the color and sequence of marking to be used. The labeling must be applied to the reel and also to the cable.

**c** Each length of cable must be permanently labeled either OPTICAL CABLE, OC, OPTICAL FIBER CABLE, or OF on the outer jacket and identified as to manufacturer and year of manufacture.

**d** Each length of cable intended for direct burial installation shall be marked with a telephone handset in compliance with Rule 350G of the 1993 National Electrical Safety Code (NESC).

**e** Each length of cable shall be identified as to the manufacturer and year of manufacturing. The manufacturer and year of manufacturing may also be indicated by other means as indicated in Paragraphs 6.1.2 through 6.1.4 of ICEA S-87-640-2005.

**f** Mark the number of fibers on the jacket.

**g** An alternative method of marking may be used if acceptable to RDUP.

**h** The completed cable must have sequentially numbered length markers in METERS or FEET at regular intervals of not more than 2 meters along the outside of the jacket. Continuous sequential numbering must be employed in a single length of cable. The numbers must be dimensioned and spaced to produce good legibility and must be approximately 3 millimeters in height. An occasional illegible marking is permissible if form the illegible mark a legible

marking is located within 2 meters cable marked in meters or 4 feet for cable marked in feet.

**i** Agreement between the actual length of the cable and the length marking on the cable jacket must be within the limits of +1 percent, -0 percent.

## 17 FIBER OPTICAL PERFORMANCE IN A FINISHED CABLE

**a** Unless otherwise specified by the purchaser, the optical performance of the fibers in a finished cable must comply with Table 8.1 through 8.3, of ICEA S-87-640-2005. These tables are reproduced below for information purposes, but the official ICEA tables are the authoritative tables.

**Table 8.1 - Attenuation coefficient performance requirements (dB/km)**

| Fiber Type | Maximum Attenuation |
|---|---|
| Multimode (50/125 ∝m) – All | 3.5/1.0 @ 850/1300 nm |
| Multimode (62.5/125 ∝m) | 3.5/1.0 @ 850/1300 nm |
| Single-mode (Class IVa) | 0.4/0.3 @ 1310/1550 nm(1) |
| NZDS Single-mode (Class IVd) | 0.3 @ 1550 nm(2) |

**Notes:**
1) The attenuation coefficient for Class IVa fibers may also be specified at 1383 nm and 1625 nm as agreed upon between manufacturer and end-user.

2) The attenuation coefficient for Class IVd fibers may also be specified at 1625 nm as agreed upon between manufacturer and end-user.

**Table 8.2 - Multimode bandwidth coefficient performance requirements (MHz•km)**

| Source Conditions | | Minimum Modal Bandwidth | | |
|---|---|---|---|---|
| | | 50/125 | | 62.5/125 |
| | | 492AAAB | 492AAAC | |
| **OFL** | 850nm | 500 | 1500 | 160 |
| | 1300 nm | 500 | 500 | 500 |
| **EMB** | 850 nm | NA | 2000 | NA |

**Table 8.3 - Point discontinuity acceptance criteria (dB)**

| Fiber Type | Maximum Attenuation at Specified Operating Wavelengths |
|---|---|
| Multimode (all) | 0.2(1) |
| Single-mode (Class IVa) | 0.1(2) |
| Single-mode (Class IVd) | 0.1(3) |

**Notes:**
1) The operational wavelengths for Multimode fibers are 850 and 1300 nm

2) The operational wavelengths for Class IVa fibers are 1310 and 1550 nm, but may also include 1383 nm and 1625 nm as agreed upon between manufacturer and end-user.

3) The operational wavelengths for Class IVd fibers is 1550 nm, but may also include 1625 nm as agreed upon between manufacturer and end-user.

**a** Measurement of the attenuation must be conducted at the wavelength specified for application and must be expressed in decibels per kilometer.

**b** Because the accuracy of attenuation measurements for single mode fibers becomes questionable when measured on short cable lengths, attenuation measurements are to be made utilizing characterization cable lengths. If the ship length of cable is less than one kilometer, the attenuation values measured on longer lengths of cable (characterization length of cable) before cutting to the ship lengths of cable may be applied to the ship lengths.

**c** Because the accuracy of attenuation measurements for multimode fibers becomes questionable when measured on short cable lengths, attenuation measurements are to be made utilizing characterization cable lengths. If the ship length of cable is less than one kilometer, the attenuation values measured on longer lengths of cable (characterization length of cable) before cutting to the ship lengths of cable may be applied to the ship lengths.

**d** Attenuation must be measured in accordance with FOTP-78.

**e** The bandwidth of multimode fibers in a finished cable shall be no less than the values specified in ICEA Table 8.2 according to Paragraph 8.3.1

**f** The maximum cutoff wavelength ($\lambda_{cc}$) for single mode fibers in a finished cable shall be as indicated in Paragraph 8.5.2 of ANSI/ICEA S-87-640-2005 (for fibers operating at 1310 nm $\lambda_{cc}$ is $\leq$ 1260 nm and at 1550 nm $\lambda_{cc}$ is $\leq$ 1480 nm),as determined per Paragraph 8.5.1 (FOTP-80) of ANSI/ICEA S-87-640-2005.

**g** The polarization mode dispersion of single mode fibers in finished cable calculated for a link shall not exceed 0.5 ps/√km per Paragraphs 8.6.1 and 8.6.2 of ANSI/ICEA S-87-640-2005. The performance prediction methodology used shall be in accordance with TIA-559.

18 **MECHANICAL REQUIREMENTS**: Fiber optic cables manufactured under this specification shall be tested by the manufacturer to determine compliance with the requirements of this specification. Unless otherwise specified, testing shall be performed at the standard conditions defined in TIA/EIA-455 (Temperature of 23±5°C, Relative Humidity of 20 to 70 %, and Atmospheric Pressure of the Site Ambient.) The standard optical test wavelengths to be used are 1550 nm single mode

and 1300 nm multi-mode, unless otherwise specified in the individual test.

**a** **Cable Low and High Bend Test**: Cables manufactured to this specifications must meet the cable low (-30 °C) and high (60 °C)temperatures bend test per Paragraph 7.21 of ANSI/ICEA except that any increase in attenuation shall be:

(1) ≤ 0.10 dB at 1550 nm for single-mode fibers; and

(2) ≤ 0.30 dB at 1300 nm for multimode fibers.

**b** **Cable Impact Test:** All cables manufactured per the requirements of this specification after being tested per the requirements of FOTP-25 without exhibiting an increase in fiber attenuation greater than 0.10 dB for single mode fibers and 0.30 dB for multimode fibers. The test must be performed using an impact force of 4 newton-meter at a temperature of -20 ± 2°C. A cracked or split in the jacket constitutes failure.

**c** **Cable Compression Test:** All cables manufactured under this specification must be capable of meeting the cable compressive loading test depicted in paragraphs 7.31.1 of ICEA S-87-640-2005, without exhibiting an increase in fiber attenuation greater than 0.10 dB for single mode fibers and 0.30 dB for multimode fibers and without cracking or splitting of the cable jacket, except that the load to be applied shall be a minimum compressive load of 440 new tons per centimeter for armored cable and 220 newtons per centimeters for non-armored cable.

**d** **Cable Twist Test:** All cables manufactured under this specification must be capable of meeting testing per FOTP-85 without exhibiting an increase in fiber attenuation greater than 0.10 dB for single mode fibers and 0.30 dB for multimode fibers, and without cracking or splitting of the cable jacket.

**e** **Cable Flex Test:**

**(1)** All cables manufactured under this specification must be capable of meeting the flex test depicted in paragraphs 7.27 and 7.27.1 without exhibiting an increase in fiber attenuation greater than 0.10 dB for single mode fibers and 0.30 dB for multimode fibers.

**(2)** At the completion of the test, the bent area of the cable must show neither visible evidence of fracture of the jacket nor delamination of the bond at the overlap and to the outer jacket in non-flooded cable. After removal of the jacket, there must be no visible evidence of fracture of the armor, when present, and of the components in the core.

**f** **Water Penetration Test:** All cables manufactured under this specification must be capable of meeting the following test:

**(1)** A one meter length of completed fiber optic cable must be pre-conditioned for 24 hours at 23 ± 5°C and then tested in accordance FOTP-82 using a one meter water head over the sample or placed under the equivalent continuous pressure for one hour.

**(2)** After the one hour period, there must be no water leakage through the sheath interfaces, under the core wrap, between the cable core interstices or through the fiber buffers.

**(3)** If water leakage is detected in the first sample, one additional 3 meter sample from EACH END of the same reel must be tested in accordance with Paragraph 17f(1) of this specification. If either sample exhibits water leakage, the entire reel of cable is to be rejected. If the samples exhibit no leakage, the entire reel of cable is considered acceptable.

**g** **Dried Core Water Immersion Test:** All cables using water blocking elements in the cable core manufactured under this specification must be capable of meeting the test depicted below to determine if the optical attenuation is affected by water entry into the core of these cable designs:

**(1)** Test sample selection. The length of the cable under test shall be of such a length to ensure that valid optical attenuation measurements are obtained for the test cable. The test sample shall be prepared by removing the jacket, shield or shield/armor, and core wrap for a sufficient distance on both ends to allow access to the individual fibers.

**(2)** Test sample preparation. Prepare the sample by removing the jacket, shield or shield/armor, and core wrap for a sufficient distance to allow one end to be accessed for test connections. A series of 6 mm (0.25 in.) diameter holes shall be cut out along the test sample, at 30 cm (1 ft) intervals progressing successively 90 degrees around the circumference of the cable. The cable core shall be exposed at each hole by slitting the core wrapper. The prepared sample shall be placed in a dry vessel that when filled will maintain a one meter (3 ft) head of water over 6 m (20 ft) of uncoiled cable. The cable ends shall be extended and fastened so they will be above the water line.

**(3)** Criterion: To meet this test the cable sample shall meet the applicable requirements below. Optical attenuation measurements shall be made at 1310 and 1550 nm for dispersion-unshifted single mode fibers and/or 1300 nm for multimode fibers.

**A** Attenuation of each single mode fiber shall not change by more than 0.1 dB/km;

**B** Attenuation of each multimode fiber shall not change by more than 0.3 dB/km; and

**C** The bandwidth of each multimode fiber shall not change by more than 15 percent from their original values.

**h** **Compound Flow Test:** All cables manufactured under this specification must be capable of meeting the following test:

**(1)** For filled cables three 300 millimeter long test samples must be pre-conditioned for 24 hours at 23 ± 5°C and then tested in accordance FOTP-81 using a test temperature of 80 ± 1°C.

**(2)** The amount of filling or flooding compounds that flowed or dripped from any of the suspended cable specimens must be less than or equal to 0.5 grams of material. The measurement of an amount greater than 0.5 grams for any of the suspended cable specimens constitutes failure.

**i** **Material Compatibility and Cable Aging Test:** All cables manufactured under this specification must be capable of meeting the Material Compatibility and Cable Aging Test depicted in paragraphs 7.19 through paragraph 9.19.2.4 of ICEA S-87-640-2005.

**j** **Cable External Freezing Test**: All cables manufactured under this specification must be capable of meeting the Cable External Freezing Test depicted in paragraphs 7.22 and 7.22.1 if ICEA S-87-640-2005 without exhibiting an increase in fiber attenuation greater than 0.10 dB for single mode fibers and 0.30 dB for multimode fibers, and without cracking or splitting of the cable jacket.

**k** **Cable Temperature Cycling Test:** All cables manufactured under this specification must be capable of meeting the Cable Temperature Cycling Test depicted in paragraph 7.24.1 of ICEA S-87-640-2005 without exhibiting an increase in fiber attenuation greater than 0.10 dB for single mode fibers and 0.30 dB for multimode fibers.

**l** **Cable Sheath Adherence Test**: All cables manufactured under this specification must be capable of meeting the Cable Sheath Adherence Test depicted in paragraph 2.26.1 and 7.26.2 of ICEA-S-87-640-2005.

**m** **Mid-Span Test:** All buried and underground loose tube single mode cables manufactured in accordance with the requirements of this specification must be capable of meeting the following mid-span

test without exhibiting an increase in fiber attenuation greater than 0.1 dB for loose tube single mode fibers.

**(1)** Measure the attenuation of dispersion-unshifted single mode fibers at 1310 ± 10 and 1550 ± 10 nm, dispersion-shifted single mode fibers at 1550 ± 10 nm.

**(2)** After measuring the attenuation of the optical fibers, test the cable sample in accordance with EIA/TIA-455-3A. The following detailed test conditions shall apply:

**(a)** Section 4.1 – Loose tube single mode optical cable sample shall be tested.

**(b)** Section 4.2 – An RDUP/RUS accepted 8 to 12 inch diameter optical buried distribution pedestal sample shall be tested.

**(c)** Mid-span opening for installation of loose tube single mode optical cable in pedestal shall be 20 feet.

**(d)** Section 5.1 – 3 hours soak time.

**(e)** Section 5.2 – Test Condition C-2, minimum –40° Celsius (-40°F) and maximum 70° Celsius (158°F).

**(f)** Section 5.7.2 – 5 transmitting fibers in all express buffer tubes passing through the pedestal and stored in the slack tray shall be measured.

**(3)** The cable may be allowed to warm to room temperature before visual inspection. The cable mid-span opening must not show visible evidence of fracture of the buffer tubes nor any degradation of all exposed cable assemblies. Fiber cable attenuation measured through the express buffer tubes during and after the test shall not exceed 0.10 db from the initial baseline measurements made in accordance with EIA/TIA-455-3A, Section 5.7.1 and Section 5.7.2 specified above. All measurements must maintain baseline attenuation levels after testing for a successful completion.

**n** **Sheath Slitting Cord Test**:

**(1)** Sample selection. All testing shall be performed on two 1.2 m (4 ft) lengths of cable removed sequentially from the same 25 pair, 22 AWG jacketed cable. This cable shall not have been exposed to temperatures in excess of 38°C since its initial cool down after sheathing.

**(2)** Test procedure.

**(a)** Using a suitable tool, expose enough of the sheath slitting cord to permit grasping with needle nose pliers.

**(b)** The prepared test specimens shall be maintained at a temperature of 23 ± 1°C for at least 4 hours immediately prior to and during the test.

**(c)** The sheath slitting cord shall be wrapped around the plier jaws to ensure a good grip.

**(d)** The cable shall be grasped and held in a convenient position while gently and firmly pulling the sheath slitting cord longitudinally in the direction away from the cable end. The angle of pull may be allowed to vary to any convenient and functional degree. A small starting notch in the jacket is permissible.

**(e)** The sheath slitting cord shall be considered acceptable if the cord can slit the jacket and/or shield or shield/armor for a continuous length of 0.6 m (2 ft) without breaking the cord.

## 19 PRECONNECTORIZED CABLE (OPTIONAL)

**a** At the option of the manufacturer and upon request by the purchaser, the cable may be factory terminated with connectors acceptable to RDUP.

**b** All connectors must be accepted by RDUPA prior to their use.

## 20 ACCEPTANCE TESTING AND EXTENT OF TESTING

**a** The tests described in Appendix A of this specification are intended for acceptance of cable designs and major modifications of accepted designs. What constitutes a major modification is at the discretion of the RDUP. These tests are intended to show the inherent capability of the manufacturer to produce cable products that have satisfactory performance characteristics, long life and long-term optical stability but are not intended as field tests. After initial RUS acceptance is granted, the manufacturer will need to apply for continued product acceptance on January three years after the year of initial acceptance.

**b** Acceptance: For initial acceptance, the manufacturer must submit:

**(1)** An original signature certification that the product fully complies with each section of this specification;

**(2)** Qualification Test Data, per Appendix A of this specification;

**(3)** A set of instructions for handling the cable;

**(4)** OSHA Material Safety Data Sheets for all components;

**(5)** Agree to periodic plant inspections;

**(6)** A certification stating weather the cables, as these are sold to RUS borrowers, complies with the following two provisions:

**(a)** Final assembly or manufacture of the product, as the product would be used by an RDUP borrower, is completed in the United States or eligible countries (currently, Mexico, Canada and Israel); and

**(b)** The cost of United States and eligible countries' components (in any combination) within the product is more than 50 percent of the total cost of all components utilized in the product. The cost of non-domestic components (components not manufactured within the United States or eligible countries) which are included in the finished product must include all duties, taxes, and delivery charges to the point of assembly or manufacture.

(7) Written user testimonials concerning performance of the product, and;

(8) Other nonproprietary data deemed necessary by the RUS.

**c** Re-qualification acceptance: For submission of a request for continued product acceptance after the initial acceptance, follow Paragraph 19a and then, on January every three years. The manufacturer shall submit an original signature certification stating that the product fully complies with each section of the specification, excluding the Qualification Section, and a certification that the products sold to RUS borrowers comply with paragraphs 20b(6) through 20b(6)(b). The tests of Appendix A shall be conducted and records kept for at least three years and the data shall be made available to RUS on request. The required data must have been gathered within 90 days of the submission. A certification shall be submitted to RUS stating that the cable manufactured to this specification has been tested per Appendix and that the cable met test requirements.

**d** Initial and re-qualification acceptance requests should be addressed to: Chairman, Technical Standards Committee "A" (Telephone), STOP 1550, Advanced Services Division, Rural

Development Utilities Programs - Telecommunications, Washington, DC 20250-1500.

**e** **Tests on 100 Percent of Completed Cable:**

**(1)** The armor for each length of cable must be tested for continuity using the procedures of ASTM D 4566-90.

**(2)** Attenuation for each optical fiber in the cable must be measured.

**(3)** Optical discontinuities must be isolated and their location and amplitude recorded.

**f** **Capability Tests:** Tests on a quality assurance basis must be made as frequently as is required for each manufacturer to determine and maintain compliance with:

**(1)** Numerical aperture and bandwidth of multimode fibers;

**(2)** Cut off wavelength of single mode fibers;

**(3)** Dispersion of single mode fibers;

**(4)** Shrinkback and cold testing of loose tube and tight tube buffers;

**(4)** Adhesion properties of the protective fiber coating;

**(6)** Dielectric strength between the armor and the metallic central member;

**(7)** Performance requirements for the inner and outer jacketing materials;

**(8)** Performance requirements for the filling and flooding compounds;

**(9)** Bonding properties of the coated armoring material;

**(10)** Sequential marking and lettering;

**(11)** Cable bend and cable impact tests;

**(12)** Water penetration, dry core water immersion, and compound flow tests;

**(13)** Cable twist, cable flex, and cable compression tests; and

**(14)** Performance requirements of support messenger.

**(15)** Cold mid-span test for single mode fiber optic cables test.

**(16)** Rip cord slitting test.

## 21 RECORDS OF OPTICAL AND PHYSICAL TESTS

**a** Each manufacturer must maintain suitable summary records for a period of at least 3 years of all optical and physical tests required on completed cable by this specification as set forth in Paragraphs 20e(1), 20e(2) and 20e(3) of this specification. The test data for a particular reel must be in a form that it may be readily available to RDUP upon request. The optical data must be furnished to the purchaser on a suitable and easily readable form.

**b** Measurements and computed values must be rounded off to the number of places or figures specified for the requirement according to ASTM E 29-90.

## 22 MANUFACTURING IRREGULARITIES

**a** Repairs to the armor, when present, are not permitted in cable supplied to the end user under this specification.

**b** Minor defects in the inner and outer jacket (defects having a dimension of 3 millimeter or less in any direction) may be repaired by means of heat fusing in accordance with good commercial practices utilizing sheath grade compounds.

**c** Buffer tube repair is permitted only in conjunction with fiber splicing.

## 23 PACKAGING AND PREPARATION FOR SHIPMENT

**a** The cable must be shipped on reels containing one continues length of cable. The diameter of the drum must be large enough to prevent damage to the cable from reeling and unreeling. The diameter must be at least equal to the minimum bending diameter of the cable. The reels must be substantial and so constructed as to prevent damage during shipment and handling.

**b** A circumferential thermal wrap or other means of protection complying with the requirements of o Appendix B of this specification must be secured between the outer edges of the reel flange to protect the cable against damage during storage and shipment. The thermal wrap must with the requirements included in the following test:

(1) **Thermal Reel Wrap Test**: This test procedures is for qualification of initial and subsequent changes in thermal reel wraps

**(a)** **SAMPLE SELECTION:** All testing must be performed on two 450 millimeter lengths of cable removed sequentially from the same fiber jacketed cable. This cable must not have been exposed to temperatures in excess of 38°C since its initial cool down after sheathing.

**(b)** **TEST PROCEDURE**

**(A)** Place the two samples on an insulating material such as wood.

**(B)** Tape thermocouples to the jackets of each sample to measure the jacket temperature.

**(C)** Cover one sample with the thermal reel wrap.

**(D)** Expose the samples to a radiant heat source capable of heating the uncovered sample to a minimum of 71°C. A GE 600 watt photoflood lamp or an equivalent lamp having the light spectrum approximately that of the sun shall be used.

**(E)** The height of the lamp above the jacket shall be 380 millimeters or an equivalent height that produces the 71°C jacket temperature on the unwrapped sample shall be used.

**(F)** After the samples have stabilized at the temperature, the jacket temperatures of the samples shall be recorded after one hour of exposure to the heat source.

**(G)** Compute the temperature difference between jackets.

**(H)** For the thermal reel wrap to be acceptable to RDUP, the temperature difference between the jacket with the thermal reel wrap and the jacket without the reel wrap shall be greater than or equal to 17°C.

**c** Cable manufactured to the requirements of this specification must be sealed at the ends to prevent entrance of moisture.

**d** The end-of-pull (outer end) of the cable must be securely fastened to prevent the cable from coming loose during transit. The start-of-pull (inner end) of the cable must project through a slot in the flange of the reel, around an inner riser, or into a recess on the flange near the drum and fastened in such a way to prevent the cable from becoming loose during installation.

**e** Spikes, staples or other fastening devices must be used in a manner which will not result in penetration of the cable.

**f** The arbor hole must admit a spindle 63.5 millimeters in diameter without binding. Steel arbor hole liners may be used but must be accepted by REA prior to their use.

**g** Each reel must be plainly marked to indicate the direction in which it should be rolled to prevent loosening of the cable on the reel.

**h** Each reel must be stenciled or lettered with the name of the manufacturer.

**i** The following information must be either stenciled on the reel or on a tag firmly attached to the reel:

OPTICAL CABLE
Number of Fibers
Armored or Nonarmored
Year of Manufacture
Name of Cable Manufacturer
Length of Cable
Reel Number
RUS 7 CFR 1755.900
Minimum Bending Radio (when radio is
independent of the outside diameter)

Example:

OPTICAL CABLE
4 fiber
Armored
XYZ Company
1050 meters
Reel Number 3
RUS 7 CFR 1755.900

**j** When pre-connectorized cable is shipped, the splicing modules must be protected to prevent damage during shipment and handling.

UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Electrification Administration

**APPENDIX A**

**FILLED FIBER OPTIC CABLE**

**Qualifications Test Methods Bulletin 1753F-601(PE-90)**

**1** The test procedures described in this appendix are for qualification of initial designs and major modifications of accepted designs. Included in Paragraph 5 of this appendix are suggested formats that may be used in submitting test results to RDUP. Also submit test results for the cold mid-span test, sheath cord slitting test, and **Thermal Reel Wrap Test** depicted in paragraph 18n and 23b(1)(a) of this specification as part of test data.

**2 SAMPLE SELECTION AND PREPARATION**

**a** All testing must be performed on lengths removed sequentially from any of the same cables listed below. The cables must not have been exposed to temperatures in excess of 38°C since their initial cool downs after sheathing. The lengths specified are minimum lengths and if desirable from a laboratory testing standpoint longer lengths may be used:

(1) 12 single mode fiber jacketed cable consisting of single mode dispersion-unshifted fibers.

(2) 12 multimode fiber jacketed cable consisting of 6 50/125 micrometer multimode fibers and 6 62.5/125 micrometer multimode fibers.

(3) 24 fiber jacketed combination cable consisting of 8 single mode dispersion-unshifted fibers; 8 50/125 micrometer multimode fibers; and 8 62.5/125 micrometer multimode fibers.

**b** Length A shall be a minimum of 500 meters long. Coil the sample with a diameter of 50 to 75 times its sheath diameter. Three lengths are required if only requesting acceptance for either single mode fiber cable (a.), multimode fiber cable (b.), or using the combination fiber cable (c.). Six lengths, 3 lengths of either single mode fiber cable (a.), and 3 lengths of multimode fiber cable (b.), are required if requesting acceptance for both single mode and multimode fiber cables.

**c** Length B shall be one meter long. Four lengths of either single mode fiber cable (a.), multimode fiber cable (b.) or the combination fiber cable (c.) are required.

**d** Length C shall be 600 millimeters long. Four lengths of either single mode fiber cable (a.), multimode fiber cable (b.) or the combination fiber cable (c.) are required.

**e** **Data Reference Temperature:** Unless otherwise specified, all measurement shall be made at 23 ± 5°C.

## 3 ENVIRONMENTAL TESTS

### a 3.1 Heat Aging Test

**(1)** **Test Samples:** Place one or two samples of length A and one sample each of lengths B and C in an oven or environmental chamber. The ends of sample A must exit from the chamber or oven for optical tests. Securely seal the oven exit holes.

**(2)** **3.1.2 Sequence of Tests:** The samples are to be subjected to the following tests after conditioning:

(a) Water Penetration Test outlined in Paragraph 3b of this appendix;
(b) Dried Core Water Penetration Test
(c) Dried Core water Immersion Test
(d) Jacket Slip Strength Test outlined in Paragraph 3.3 of this appendix. (For Flooded Designs Only)

**(3)** **3.1.3 Initial Measurements**

**(a)** For sample(s) A measure the attenuation for the single mode dispersion-unshifted fibers at 1310 and 1550 nm, for single mode dispersion-shifted fibers at 1550 nm and/or for multimode fibers at 1300 nm at a temperature of 23 ± 5°C. Also measure the bandwidth of the multimode fibers. Calculate the attenuation data on a per kilometer basis. Calculate the bandwidth data on a megahertz-kilometer (MHz-km) basis.

**(b)** Record on suggested formats in Paragraph 5 of this appendix or on other easily readable formats.

**(4)** **3.1.4 Heat Conditioning**

**(a)** Immediately after completing the initial measurements, condition the sample(s) for 14 days at a temperature of 65 ± 2°C.

**(b)** At the end of this period note any exudation of cable filler. Measure the parameters given in Paragraph 3.1.3 of this appendix. Record on suggested formats in Paragraph 5 of this appendix or on other easily readable formats.

**(5)** **3.1.5 Overall Optical Deviation**

**(a)** Calculate the change in all parameters between the final parameters after conditioning with initial parameters in Paragraph 3a(3) of this appendix.

**(b)** The stability of the optical parameters after completion of this test must be within the following prescribed limits:

(1) Attenuation: The attenuation of each multimode fiber must not change by more than 0.3 db/km and the attenuation of each single mode fiber must not change by more than 0.1 dB/km.

(2) Bandwidth: The bandwidth of each multimode fiber must not change by more than 15 percent from their original values.

**b 3.2 Water Penetration Testing**

**(1)** A watertight closure must be placed over the jacket of length B from Paragraph 3.1.1 of this appendix. The closure must not be placed over the jacket so tightly that the flow of water through pre-existing voids or air spaces is restricted. The other end of the sample must remain open.

**(2)** Test per Option A or Option B.

**(a)** **Option A:** Weigh the sample and closure prior to testing. Fill the closure with water and place under a continuous pressure of 10 ± 0.7 kilopascals for one hour. Collect the water leakage from the end of the test sample during the test and weigh to the nearest 0.1 gram. Immediately after the one hour test, seal the ends of the cable with a thin layer of grease and remove all visible water from the closure, being careful not to remove water that penetrated into the core during the test. Reweigh the sample and determine the weight of water that penetrated into the core.

**(b)** **Option B:** Fill the closure with a 0.2 gram sodium fluorscein per liter water solution and apply a continuous pressure of 10 ± 0.7 kilopascals for one hour. Catch and weigh any water that leaks from the end of the cable during the one hour period. If no water leaks from the sample, carefully remove the water from the closure. Then carefully remove the outer jacket, armor, if present, inner jacket, if present, and core wrap one at a time, examining with an ultraviolet light source for water penetration. After removal of the core wrap, carefully dissect the core and examine for water penetration within the core. Where water penetration is observed, measure the penetration distance.

**c** **Jacket Slip Strength Test** (For Flooded Design Only)

**(1)** **Sample Selection:** Test sample C from Paragraph 3a(1) of this appendix.

**(2)** **Sample Preparation:** Prepare test sample in accordance with the procedures specified in ASTM D 4565-90a.

**(3)** **Sample Conditioning and Testing:** Remove the sample from the tensile tester prior to testing and condition for one hour at 50 ± 2°C. Test immediately in accordance with the procedures specified in ASTM D 4565-90a. A minimum jacket slip strength of 67 newtons is required. Record the load attained on the suggested formats in Paragraph 5 of this appendix or on other easily readable formats.

**d** **3.4 Temperature and Humidity Exposure**

**(1)** Repeat Paragraphs 3a(1) through 3a(3)(b) of this appendix for separate set of samples A, B and C which have not been subjected to prior environmental conditioning.

**(2)** Immediately after completing the measurements, expose the test sample to 100 temperature cyclings. Relative humidity within the chamber shall be maintained at 90 ± 2 percent. One cycle consists of beginning at a stabilized chamber and test sample temperature of 52 ± 2°C, increasing the temperature to 57 ± 2°C, allowing the chamber and test samples to stabilize at this level, then dropping the temperature back to 52 ± 2°C.

**(3)** **2**Repeat Paragraphs 3a(4)(b)(3.1.4.2) through 3c(3)(3.3.3) of this appendix.

**e** **3.5 Temperature Cycling**

**(1)** Repeat Paragraphs 3.1.1 through 3.1.3.2 of this appendix for separate set of samples A, B, and C which have not been subjected to prior environmental conditioning.

**(2)** Immediately after completing the measurements, subject the test sample to 10 cycles of temperature between -40°C and +70°C. The test sample must be held at each temperature extreme for a minimum of 1-1/2 hours during each cycle of temperature. The air within the temperature cycling chamber must be circulated throughout the duration of the cycling.

**(3)** Repeat Paragraphs 3a(4)(2)(3.1.4.2) through 3c(3)(3.3.3) of this appendix.

**4 CONTROL SAMPLE**

**a** **Test samples:** A separate set of lengths B and C must have been maintained at 23 ± 5°C for at least 48 hours before the testing.

**b** Repeat Paragraphs 3b(3.2) through 3c(3)(3.3.3) of this appendix for these samples.

5.

**5 TEST DATA FORMATS**

**a** The following suggested formats may be used in submitting the test results to REA.

Heat Aging Test - Single Mode Cable

| Fiber No. | Attenuation - 1310 nm dB/km | | | Attenuation - 1550 nm dB/km | | |
|---|---|---|---|---|---|---|
| | Initial | Final | Change | Initial | Final | Change |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |

Heat Aging Test - Multimode Cable

| Fiber No. | Attenuation - 1300 nm dB/km | | | Bandwidth MHz-km | | |
|---|---|---|---|---|---|---|
| | Initial | Final | Change | Initial | Final | Change(%) |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |

Heat Aging Test - Combination Cable

| Fiber No. | Attenuation - 1310 nm dB/km | | | Attenuation - 1550 nm dB/km | | | Bandwidth MHz-km | | |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | Final | Change | Initial | Final | Change | Initial | Final | Change(%) |
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
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Temperature/Humidity Test - Single Mode Cable

| Fiber No. | Attenuation - 1310 nm dB/km | | | Attenuation - 1550 nm dB/km | | |
|---|---|---|---|---|---|---|
| | Initial | Final | Change | Initial | Final | Change |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |

Temperature/Humidity Test - Multimode Cable

| Fiber No. | Attenuation - 1300 nm dB/km | | | Bandwidth MHz-km | | |
|---|---|---|---|---|---|---|
| | Initial | Final | Change | Initial | Final | Change(%) |
| 1 | | | | | | |
| 2 | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | _____ | _____ | _____ | _____ | _____ | _____ |
| 4 | _____ | _____ | _____ | _____ | _____ | _____ |
| 5 | _____ | _____ | _____ | _____ | _____ | _____ |
| 6 | _____ | _____ | _____ | _____ | _____ | _____ |
| 7 | _____ | _____ | _____ | _____ | _____ | _____ |
| 8 | _____ | _____ | _____ | _____ | _____ | _____ |
| 9 | _____ | _____ | _____ | _____ | _____ | _____ |
| 10 | _____ | _____ | _____ | _____ | _____ | _____ |
| 11 | _____ | _____ | _____ | _____ | _____ | _____ |
| 12 | _____ | _____ | _____ | _____ | _____ | _____ |

Temperature/Humidity Test - Combination Cable

| Fiber No. | Attenuation - 1310 nm dB/km | | | Attenuation - 1550 nm dB/km | | | Bandwidth MHz-km | | |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | Final | Change | Initial | Final | Change | Initial | Final | Change(%) |
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
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| 23 | | | | | | | | | |
| 24 | | | | | | | | | |

Temperature Cycling Test - Single Mode Cable

| Fiber No. | Attenuation - 1310 nm dB/km | | | Attenuation - 1550 nm dB/km | | |
|---|---|---|---|---|---|---|
| | Initial | Final | Change | Initial | Final | Change |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |

Temperature Cycling - Multimode Cable

| Fiber No. | Attenuation - 1300 nm dB/km | | | Bandwidth MHz-km | | |
|---|---|---|---|---|---|---|
| | Initial | Final | Change | Initial | Final | Change(%) |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |

Temperature Cycling Test Combination Cable

| Fiber No. | Attenuation - 1310 nm dB/km | | | Attenuation - 1550 nm dB/km | | | Bandwidth MHz-km | | |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | Final | Change | Initial | Final | Change | Initial | Final | Change(%) |
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
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| 21 | | | | | | | | | |
| 22 | | | | | | | | | |
| 23 | | | | | | | | | |
| 24 | | | | | | | | | |

Water Penetration Test

| | Option A | | Option B | |
|---|---|---|---|---|
| | End Leakage grams | Weight Gain grams | End Leakage grams | Penetration millimeters |
| Control | _____ | _____ | _____ | _____ |
| Heat Age | _____ | _____ | _____ | _____ |
| Humidity Exposure | _____ | _____ | _____ | _____ |
| Temperature Cycling | _____ | _____ | _____ | _____ |

Jacket Slip Strength @ 50°C (load in newtons)

Control _____

Heat Age _____

Humidity Exposure _____

Temperature Cycling _____

Filler Exudation (grams)

Heat Age _____

Humidity Exposure _____

Temperature Cycle _____